FORM PTO-1390 (REV 5-93) U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: **1934/49556**

U S APPLICATION NO (if known, see 37 CFR 1 5): 09/744471

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/GB99/02223	**26 July 1999 (26.07.99)**	**25 July 1998 (25.07.98)**

TITLE OF INVENTION: **APPARATUS, METHOD OF AND SYSTEM FOR IMPROVING CAPACITY IN A COMMUNICATIONS NETWORK**

APPLICANT(S) FOR DO/EO/US: **Harald HAAS and Gordon Johnston Robertson POVEY**

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.

2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371

3. [ ] This express request to begin national examination procedures (35 U.S.C. 371(f) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).

4. [X] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.

5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2)).

   a. [X] is transmitted herewith (required only if not transmitted by the International Bureau).

   b. [ ] has been transmitted by the International Bureau

   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US)

6. [ ] A translation of the International Application into English (35 U.S.C. 371(c)(2)).

7. [ ] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))

   a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).

   b. [ ] have been transmitted by the International Bureau.

   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.

   d. [ ] have not been made and will not be made.

8. [ ] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).

9. [X] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). **UNEXECUTED (2 pages)**

10. [X] A copy of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Item 11. to 16. below concern other document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.

12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.

13. [X] A FIRST preliminary amendment.

    [ ] A SECOND or SUBSEQUENT preliminary amendment.

14. [ ] A substitute specification.

15. [ ] A change of power of attorney and/or address letter.

16. [X] Other items or information: **Seven (7) sheets of drawings showing Figures 1, 2, 3, 4, 5, 6 and 7; International Preliminary Examination Report with Amended Sheets; First page of Published International Application**

U.S. APPLICATION NO (if known, see 37 CFR 1.5) 09/744471	INTERNATIONAL APPLICATION NO PCT/GB99/02223	ATTORNEY'S DOCKET NUMBER /

17. [X] The following fees are submitted:	CALCULATIONS	PTO USE ONLY
Basic National Fee (37 CFR 1.492(a)(1)-(5)):		
Search Report has been prepared by the EPO or JPO $860.00	**$ 860.00**	
International preliminary examination fee paid to USPTO (37 CFR 1.482) ... $690.00		
No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2) $710.00		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37CFR 1.445(a)(2) paid to USPTO ..... $ 1000.00		
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $100.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ **860.00**	
Surcharge of $130.00 for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$ **130.00**	

Claims	Number Filed	Number Extra	Rate		
Total Claims	22-20=	2	X $18.00	$ **36.00**	
Independent Claims	4-3=	1	X $80.00	$ **80.00**	
Multiple dependent claims(s) (if applicable)			+ $270.00	$	
TOTAL OF ABOVE CALCULATIONS =				$ **246.00**	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).				$	
SUBTOTAL =				$ **1,106.00**	
Processing fee of $130.00 for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$ **1,106.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28,3.31). $40.00 per property +				$	
TOTAL FEE ENCLOSED =				$ **1,106.00**	
				Amount to be: refunded	$
				charged	$

a. [X] A check in the amounts of $ **1,106.00** to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. _____ in the amount of $_____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees, which may be required, or credit any overpayment to Deposit Account No. 05-1323 . (Attorney Docket No. **1934/49556** .) A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Evenson, McKeown, Edwards & Lenahan, P.L.L.C.
1200 G Street, N.W., Suite 700
Washington, D.C. 20005
Tel. No. (202) 628-8800
Fax No. (202) 628-8844

Gary R. Edwards

SIGNATURE

Gary R. Edwards

NAME

31,824

REGISTRATION NUMBER

25 January 2001

DATE

Attorney Docket: 1934/49556
PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: HARALD HAAS ET AL.

Serial No.: NOT YET ASSIGNED PCT No.: PCT/GB99/02223

Filed: JANUARY 25, 2001

Title: APPARATUS, METHOD OF AND SYSTEM FOR IMPROVING CAPACITY IN A COMMUNICATIONS NETWORK

PRELIMINARY AMENDMENT

Box PCT January 25, 2001
Commissioner for Patents
Washington, D.C. 20231

Sir:

Please enter the following amendments to the specification and claims, as amended by way of Annexes to the International Preliminary Examination Report for PCT/GB99/02223, prior to the examination of the application during the U.S. National Phase.

IN THE CLAIMS:

Please amend the claims as follows:

(A copy of the marked up version of amended claims are attached as an appendix to this amendment.)

6. (Amended) A system as claimed in Claim 1, wherein at least a portion of the frequency allocation of the first duplexing technique is used to transmit FDD downlink traffic

during substantially all time slots associated with the second duplexing technique.

7. (Amended) A system as claimed in Claim 1, wherein a terminal operating in accordance with the second duplexing technique within the band of frequencies allocated to the first duplexing technique is arranged to transmit delay-tolerant data.

8. (Amended) A system as claimed in Claim 1, wherein a terminal operating in accordance with the second duplexing technique within the band of frequencies allocated to the first duplexing technique is arranged to receive delay-tolerant data.

9. (Amended) A system as claimed in Claim 7, wherein the delay-tolerant data is packet data.

10. (Amended) A system as claimed in Claim 1, wherein the means provided for allocating spare capacity is arranged to determine a band of frequencies within a respective frequency band associated with the first duplexing system on the basis of mutual interference criteria.

11. (Amended) A system as claimed in Claim 9, wherein the delay-tolerant data is packet data.

13. (Amended) A system as claimed in Claim 1, wherein the second base station is located between about 200 and 500m from the first base station.

14. (Amended) A system as claimed in Claim 1, wherein the second plurality of terminals includes the terminal.

15. (Amended) A system as claimed in Claim 1, wherein the terminal is a new terminal previously unaffiliated to the second base station.

REMARKS

Entry of the amendments to the claims, as amended by way of Annexes to the International Preliminary Examination Report for PCT/GB99/02223, before examination of the application in the U.S. National Phase is respectfully requested. The claims have been amended to remove multiple dependencies.

If there are any questions regarding this Preliminary Amendment or this application in general, a telephone call to the undersigned would be appreciated since this should expedite the prosecution of the application for all concerned.

If necessary to effect a timely response, this paper should be considered as a petition for an Extension of Time sufficient to effect a timely response, and please charge any deficiency in fees or credit any overpayments to Deposit Account No. 05-1323 (Docket #1934/49556).

Respectfully submitted,

Gary R. Edwards
Registration No. 31,824

EVENSON, McKEOWN, EDWARDS
& LENAHAN, P.L.L.C.
1200 G Street, N.W., Suite 700
Washington, DC 20005
Telephone No.: (202) 628-8800
Facsimile No.: (202) 628-8844
GRE:kms

Appendix to Amendment

(Marked up version of amended claims)

6. (Amended) A system as claimed in [any preceding claim,] Claim 1, wherein at least a portion [(110)] of the frequency allocation of the first duplexing technique [(100)] is used to transmit FDD downlink traffic during substantially all time slots associated with the second duplexing technique [(102)].

7. (Amended) A system as claimed in [any preceding claim,] Claim 1, wherein a terminal [(U1)] operating in accordance with the second duplexing technique within the band [(108)] of frequencies allocated to the first duplexing technique is arranged to transmit delay-tolerant data.

8. (Amended) A system as claimed in [any preceding claim,] Claim 1, wherein a terminal [(U1)] operating in accordance with the second duplexing technique within the band [(108)] of frequencies allocated to the first duplexing technique is arranged to receive delay-tolerant data.

9. (Amended) A system as claimed in [Claim 7 or Claim 8,] Claim 7, wherein the delay-tolerant data is packet data.

10. (Amended) A system as claimed in [any preceding claim,] Claim 1, wherein the means [(404)] provided for allocating spare capacity is arranged to determine a band [(400, 402)] of frequencies within a respective frequency band [(108, 110)] associated with the first duplexing system [(100)] on the basis of mutual interference criteria.

11. (Amended) A system as claimed in Claim 9 [or Claim 10], wherein the delay-tolerant data is packet data.

13. (Amended) A system as claimed in [any preceding claim] Claim 1, wherein the second base station [(116)] is located between about 200 and 500m from the first base station [(106)].

14. (Amended) A system as claimed in [any preceding claim] Claim 1, wherein the second plurality of terminals [(114, U1, U2,.....Un)] includes the terminal [(U1)].

15. (Amended) A system as claimed in [any of claims 1 - 13,] Claim 1, wherein the terminal [(Un+1)] is a new terminal previously unaffiliated to the second base station [(116)].

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APPARATUS, METHOD OF AND SYSTEM FOR IMPROVING CAPACITY IN A COMMUNICATIONS NETWORK

The present invention relates to an apparatus, a method of and a system for improving capacity in a communications network of the type employing a first duplex technique and a second duplex technique, for example, a cellular communications system such as the Universal Mobile Telecommunication System (UMTS).

In order to achieve a two way communication (duplex) in a communications system, each direction of communication, i.e. from a mobile terminal to a base station (hereinafter referred to as the "uplink") and from the base station to the mobile terminal (hereinafter referred to as the "downlink"), must be separated in order to avoid inter-network interference, i.e. uplink transmissions jamming downlink transmissions, and vice versa. The separation can be achieved either in the frequency domain or the time domain.

Referring to Figure 1, a schematic diagram of bandwidth allocations for a UMTS is shown. The UMTS supports two duplex techniques, namely a Frequency Division Duplex (FDD) technique 100 and a Time Division Duplex (TDD) technique 102. For FDD, uplink communications between an FDD terminal 104 and an FDD base station 106 are via a first band of frequencies 108 and downlink communications between the FDD terminal 104 and the FDD base station 106 are via a second, different, band of frequencies 110. The two bands of frequencies 108, 110 used by the FDD technique are separated by a further frequency band, known as a duplex distance 112.

The TDD technique permits communication between a TDD terminal 114 and a TDD base station 116 in a single, unpaired, band of frequencies

118, but with time gaps, known as guard times 120, between periods of transmission and reception.

Figure 2 is a schematic diagram showing in more detailed the allocation of bandwidth shown in Figure 1. For symmetric traffic and a single switching point, the band of TDD frequencies 118 are sub-divided into 16 time slots t_0, ..., t_{15}, of which the first eight time slots t_0, ..., t_7 are dedicated to downlink traffic and the remaining eight time slots t_8, ..., t_{15} are dedicated to uplink traffic.

In the UMTS, a plurality of TDD terminals U_1, ..., U_n are capable of communicating with the TDD base station 116. A first predetermined number of terminals U_1, ..., U_m are allocated the first time slot t_0 for downlink transmissions and the ninth time slot t_8 for uplink transmissions. Similarly, other predetermined numbers of terminals are allocated other time slots for uplink and downlink communications.

Taking the first TDD terminal U_1 of the first predetermined number of terminals U_1, ..., U_m, it will be appreciated that after being active during the first time slot t_0, the first TDD terminal is effectively idle 200 until the beginning of the ninth time slot t_8, i.e. no transmission or reception is taking place. The first TDD terminal U_1 is similarly inactive 202 after the ninth time slot t_8 until the beginning of the first slot t_0 of a succeeding frame. Therefore, it can be seen that each TDD terminal is only actively handling communications traffic for 1/8 of the duration of the frame. For CDMA, in contrast, communications traffic from FDD terminals occupy whole frames in the FDD bands of frequencies 108, 110 with instantaneously transmitting and receiving signals.

The above periods of inactivity are also experienced by the other TDD terminals U_2, ..., U_n; the second to m^{th} TDD terminal U_2, ..., U_m are idle during the same periods of time as the first TDD terminal U_1, the remaining

TDD terminals U_{m+1}, ..., U_n being idle during different periods of time depending upon the time slots to which they are allocated.

With the increase of mobile data applications, for example, video, facsimile and file download from the Internet, the variable data rates and packet oriented services associated with these applications and the limited amount of radio resources allocated to a given communications system make demands on the air interface and cellular architecture associated with the system.

Consequently, the European Telecommunications Standards Institute (ETSI) UMTS standard permits the use of macro-, micro- and pico-cells, where the macro cells ensure overall coverage of a geographic area and the micro-, or even pico-cells, support areas of high telecommunications traffic, for example, hotels or airports. Additionally, as mentioned above, the UMTS will support two duplex techniques, namely the FDD technique and the TDD technique.

In the UMTS, due to the increase in the above described mobile data applications, large volumes of traffic are likely on the downlink. Consequently, due to the asymmetry caused by data traffic on the downlink, at least the uplink band of frequencies for the FDD technique is underused. Hence, unused radio resources allocated to the FDD technique represent a waste of channel capacity, especially when the TDD base station 116 is at maximum load. Handover between a TDD cell and an FDD cell may not be possible, because a TDD terminal may not be able to support the FDD technique, i.e. no dual mode capability, or the FDD cell and the TDD cell may not be run by the same operator. Hence, it should be understood that the term "system" is intended to include more than one communications system comprising at least one respective duplexing technique, or a single system comprising at least two duplexing techniques.

may not be run by the same operator. Hence, it should be understood that the term "system" is intended to include more than one communications system comprising at least one respective duplexing technique, or a single system comprising at least two duplexing techniques.

It is therefore an object of the present invention to obviate, or at least mitigate the above-described problems caused by asymmetry of telecommunications traffic.

According to a first aspect of the invention there is provided a communications system comprising a first duplexing technique to enable communication between a first base station and a first plurality of terminals, a second duplexing technique to enable communication between a second base station and a second plurality of terminals; the first and second base stations serving terminals in respective but at least overlapping areas and the first and second duplexing techniques having respective frequency bands associated therewith, characterised in that: the first duplexing technique comprises a Frequency Division Duplex (FDD) technique; the second duplexing technique comprises a Time Division Duplex (TDD) technique; and that, in order to increase the communications-handling capacity of the system, provision is made for detecting spare capacity in a frequency band associated with the FDD technique, and for allocating spare capacity so detected to support TDD communication between said second base station and one or more of said second plurality of terminals without interrupting contemporaneous FDD communication between said first base station and said first plurality of terminals.

According to a second aspect of the invention, there is provided a method of improving capacity in a communications system comprising a

first duplexing technique to enable communication between a first base station and a first plurality of terminals, a second duplexing technique to enable communication between a second base station and a second plurality of terminals; the first and second base stations serving terminals in respective but at least overlapping areas and the first and second duplexing techniques having respective frequency bands associated therewith, characterised by:

the first duplexing technique utilising Frequency Division Duplex (FDD); the second duplexing technique utilising Time Division Duplex (TDD); and by the steps of:

detecting spare capacity in a frequency band associated with the FDD technique; and

allocating spare capacity so detected to support TDD communication between said second base station and one or more of said second plurality of terminals without interrupting contemporaneous FDD communication between said first base station and said first plurality of terminals.

According to a third aspect of the invention, there is provided a terminal for use in a system comprising a first duplexing technique to enable communication between a first base station and a first plurality of terminals, a second duplexing technique to enable communication between a second base station and a second plurality of terminals; the first and second base stations serving terminals in respective but at least overlapping areas and the first and second duplexing techniques having respective frequency bands associated therewith, characterised by the first duplexing technique comprising a Frequency Division Duplex (FDD) technique; the second duplexing technique comprising a Time Division Duplex (TDD) technique; and by the terminal being arranged

to receive an allocation of at least a portion of a frequency band associated with the first duplexing technique and to operate in accordance with the second duplexing technique within said frequency band associated with the first duplexing technique.

According to a fourth aspect of the invention, there is provided a base station for use in a system comprising a first duplexing technique to enable communication between another base station and a first plurality of terminals, the first-mentioned base station supporting a second duplexing technique for communication with a second plurality of terminals; the first and second base stations serving terminals in respective but at least overlapping areas and the first and second duplexing techniques having respective frequency bands associated therewith, characterised by the first duplexing technique comprising a Frequency Division Duplex (FDD) technique; the second duplexing technique comprising a Time Division Duplex (TDD) technique; and by the first-mentioned base station being arranged to allocate at least a portion of a frequency band associated with the first duplexing technique to a terminal so as to enable the terminal to operate in accordance with the second duplexing technique within said frequency band associated with the first duplexing technique.

It is thus possible to provide an apparatus, a method of and a system for improving capacity in a communications network in which the capacity of the second base station can be increased by approximately 40% by converting unused radio resources of the first base station when the load on the first base station is approximately 30%. Due to an increase in spectral efficiency, it is also possible to maintain a large guard time and hence increase the radius of the cell supported by the second base station. The increased spectral efficiency results in

higher data throughput and is achieved without filter adjustments to FDD terminals and base stations. Since minimal hardware and/or software modifications are necessary, the additional cost of implementing the present invention is minimal. Also, it is possible to assign different uplink and downlink capacities for a given terminal in the TDD cell, thereby obviating the need to change the switching point of the TDD cell. Also, asynchronous overlap with adjacent TDD cells is prevented.

Other, preferred, features and advantages are set forth in, and will become apparent from, the following description and accompanying dependent claims.

It is known, from US-A-5 732 076, to share capacity between systems operated in accordance with differing mobile communications protocols. However, the arrangement disclosed therein aims principally to promote user mobility between different communication systems without the need to purchase several sets of hardware, and moreover requires the different systems to operate in totally separate and non-overlapping time slots, thereby placing considerable demands upon synchronisation controls used to closely interleave the time slots of the two systems, so as to avoid collisions, and rendering the user capacity dependent upon time slot availability.

At least one embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 3 is a schematic diagram of mobile terminals and base stations constituting an example of the invention;

Figure 4 is a schematic diagram of bandwidth allocation for the example of Figure 3;

Figure 5 shows, in more detail, the use of bandwidth allocated to a TDD technique in Figure 4;

Figure 6 is a schematic diagram of bandwidth use constituting an embodiment of the invention; and

Figure 7 is a graph illustrating improved system performance due to the embodiment of Figure 6.

Throughout the description, identical reference numerals will be used to identify like parts.

In a first embodiment of the invention, a UMTS 300 (Figure 3) comprises an FDD cell 302 supported by the FDD base station 106. A first TDD micro-cell 306, a second TDD micro-cell 308 and a third TDD micro-cell 310 are located substantially within the FDD cell 302 and are supported by a first TDD base station 116, a second TDD base station 314 and a third

of a Radio Frequency (RF) interface. The plurality of FDD terminal 318 include the FDD terminal 104 described above.

The first TDD base station 116 is located within the first TDD cell 306 and is in communication with a plurality of TDD mobile terminals U_1, ..., U_n. Additionally, the first TDD base station 116 is synchronised with the FDD base station 106 so that data frames are aligned.

In operation (figure 4), the FDD uplink band of frequencies 108 and the FDD downlink band of frequencies 110 form a paired band of frequencies. The FDD terminal 104 transmits uplink communications traffic to the FDD base station 106 using the uplink band of frequencies 108. Similarly, the FDD terminal 104 receives transmissions from the FDD base station 106 via the downlink band of frequencies 110.

The TDD technique uses the single band of frequencies 118 described above which serves both uplink and downlink communications traffic between, for example, the first TDD mobile terminal U_1 and the first TDD base stations 116. In the case of the first TDD terminal U_1, uplink transmissions take place during the first time slot t_0 and downlink transmissions take place during the ninth time slot t_8.

A frequency allocation unit (FAU) 404 verifies that at least a portion 400, 402 of the FDD uplink band of frequencies 108 is not being used for the transmission of FDD traffic and, using a Dynamic Channel Allocation (DCA) algorithm, determines which band of frequencies within the portion of the band of FDD uplink frequencies to use on the basis of mutual interference considerations. Subsequently, the first TDD terminal U_1 is instructed by the first TDD base station 116 to use one of the available uplink frequencies 400 allocated to the FDD technique for the transmission of uplink data, in time slots, according to the TDD technique. Similarly, if there are sufficient uplink frequencies available, i.e. capacity, one of the available FDD uplink

frequencies 402 is used by the first TDD base station 116 to transmit downlink data in time slots according to the TDD technique.

Referring to Figure 5, the above-described embodiment can be seen in more detail. A Time Division-Code Division Multiple Access (TD-CDMA) scheme is used by the first TDD base station 116 in order to provide multiple access to the plurality of TDD terminals U_1, ..., U_n; the FDD base station 106 employs a Wideband CDMA (W-CDMA) multiple access scheme. The first time slot t_0 is allocated to a set of the TDD terminals U_1, ..., U_m for uplink traffic. Similarly, the ninth time slot t_8 is allocated to the set of the TDD terminals U_1, ..., U_m for downlink traffic. The uplink traffic and downlink traffic of the remaining mobile terminals U_{m+1},..., U_n is transmitted during the remaining time slots t_1,...,t_7 and t_9,...,t_{15}.

For simplicity of description and clarity, this embodiment of the invention will now be described with reference to the first TDD terminal U_1. The first TDD base station 116 is arranged to transmit CDMA encoded data to the first TDD terminal U_1 during the first timeslot t_0. After receiving the data transmitted by the first TDD base station 116 during the first time slot t_0, the FAU 404 monitors the band of FDD uplink frequencies 108 in order to determine whether or not there exists capacity in the band of FDD uplink frequencies 108, i.e. frequencies which are not being used by the FDD base station 106. If frequencies are available in the band of FDD uplink frequencies 108, the first TDD base station 116 instructs the first TDD terminal U_1 to re-tune to a frequency which are known to be available in the band of FDD uplink frequencies 108. The first TDD base station 116 then continues to transmit time slots of CDMA encoded data to the first TDD terminal U_1 in the band of available frequencies.

Additionally, if sufficient capacity 500 is available within the band of FDD uplink frequencies 108 during the first time slot t_0, the available

capacity 500 can be used by at least one of the TDD terminals U_1, ..., U_m to transmit data whilst receiving data from the first TDD base station 116 (assuming the TDD terminal in question is capable of simultaneous transmission and reception). It should be appreciated that such dual functionality is not limited to the duration of the first time slot t_0 and that such functionality can be provided whenever capacity is available within the uplink band of frequencies 108.

At a predetermined period of time prior to the beginning of the ninth time slot t_8, the first TDD terminal U_1 re-tunes to an appropriate frequency within the band of TDD frequencies 118 in order to transmit CDMA encoded data to the first TDD base station 116 during the ninth time slot t_8.

Again, the dual functionality operation, i.e. simultaneous transmission and reception, can take place during the ninth time slot t_8, provided capacity is available within the uplink band of FDD frequencies 108.

Subsequent to the ninth time slot t_8, the FAU 404 again monitors the band of FDD uplink frequencies 108 in order to determine whether or not further available capacity exists within the band of FDD uplink frequencies 108. If capacity exists within the band of FDD uplink frequencies 108, the first TDD base station 116 instructs the first TDD terminal to re-tune to the available frequency 402 within the FDD uplink frequencies in order to continue transmitting TD-CDMA encoded data to the first TDD base station 116, the first TDD terminal U_1 re-tuning to an appropriate frequency in the TDD band of frequencies 118 at a predetermined period of time prior to the commencement of the first time slot t_0 in a subsequent frame.

It should be appreciated that instead of transmitting data to the first TDD base station 116, the available capacity in the band of FDD uplink frequencies 108 can be used by the first TDD base station 116 to transmit further data to the first TDD terminal U_1. Similarly, instead of transmitting

data to the first TDD terminal U_1, the available capacity in the band of FDD uplink frequencies 108 can be used by the first TDD base station 116 to receive further data from the first TDD terminal U_1.

In a second embodiment of the invention, instead of using the available capacity within the band of FDD uplink frequencies 108 for the transmission of additional data by existing TDD terminals U_1, ..., U_n, the additional capacity can be used to permit a new TDD terminals U_{n+1} to communicate with the first TDD base station 116. It should be appreciated that more than one new TDD terminal can be supported by the system provided the band of uplink frequencies 108 has sufficient capacity to support traffic from or to the more than one new TDD terminal.

The use of the band of FDD uplink frequencies 108 by the new TDD terminal U_{n+1} or the use by existing TDD terminals U_1, ..., U_n of the band of FDD uplink frequencies 108 can cause some additional interference within the band of FDD uplink frequencies. However, if the first TDD micro-cell 306 is separated from the FDD base station by walls of a building or by a distance r_b, the additional interference will not greatly affect any FDD link. Since there are two possible bands of frequencies for placing the additional TDD link, i.e. the uplink or the downlink band of FDD frequencies 108, 110, the DCA algorithm can be employed in order to select the band of frequencies which will result in the least mutual interference. In most cases, this will be the band of FDD uplink frequencies 108.

In a third embodiment of the invention, a CDMA-TDD scheme is employed within the TDD band of the frequencies 118 (Figure 6). The CDMA-TDD scheme comprises a first time slot ts_0 and a second time slot ts_1 separated by a guard time t_g. The guard time t_g is provided in order to avoid collisions between transmitting and receiving time slots ts_0, ts_1, because there is always a delay caused by signal propagation and signal processing; these

delays are summarised and referred to as a round trip delay t_{rd}. A terminal U_m located at the boundary of the first TDD micro-cell 306 suffers from the greatest round trip delay t_{rd}. In contrast, the first TDD terminal U_1 is assumed to be closer to the first TDD base station 116, resulting in less round tip delay t_{rd}.

During operation, the plurality of TDD terminals U_1, ..., U_n transmit CDMA encoded data for the duration of the first time slot ts_0. During the first time slot ts_0, the FAU 404 monitors the band of FDD uplink frequencies 108 in order to determine whether or not capacity exists within the band of FDD uplink frequencies 108. If capacity exists amongst the band of FDD uplink frequencies 108, the first TDD base station 116 permits the new TDD terminal U_{n+1} to communicate with the first TDD base station 116. After the first time slot ts_0 has expired, and if capacity still exists amongst the band of FDD uplink frequencies 108, the first TDD base station 116 either permits the new TDD terminal U_{n+1} to continue transmitting or receiving data to/from the first TDD base station 116. Alternatively, or additionally, the first TDD base station 116 permits one of the existing plurality of TDD terminals U_1, ..., U_n, for example, the first TDD terminal U_1 to re-tune to one of the available frequencies within the band of FDD uplink frequencies 108, and to continue receiving CDMA encoded data from the first TDD base station 116. If the first TDD terminal U_1or the new terminal U_{n+1} is to use available frequencies in the band of uplink frequencies 108, it is preferable, but not essential, for the first TDD terminal U_1 or the new terminal U_{n+1} to transmit or receive packet oriented data. The transmission or reception of packet oriented data is preferable because the available capacity in the band of FDD frequencies 108 cannot be guaranteed at any time and so should be used for very low priority traffic which does not require a guaranteed response time.

At a predetermined period of time prior to the beginning of the second time slot ts_1, the first TDD terminal U_1 re-tunes to the band of TDD frequencies 118 or in the case of the new user U_{n+1}, the new user U_{n+1} can enter a transmit mode in order to transmit data to the first TDD base station 116.

Although the above embodiments illustrate the use of available frequencies within the band of FDD uplink frequencies 108, the FAU 404 can be arranged to determine whether capacity exists within the band of FDD downlink frequencies 110 for use by the first TDD base station 116 and the plurality of TDD terminals affiliated thereto. Consequently, the first TDD base station 116 then either instructs an existing TDD terminal to re-tune to the available frequency or instructs the new TDD terminal U_{n+1} to use the available frequency 400, 402.

Referring to Figure 7, in simulations where r_b is between 300m and 500m and the TDD base station 116 is placed within this area and the plurality of TDD terminals $U_1, \ldots, U_n$ are equally distributed, there is additional capacity within the band of FDD uplink frequencies when there are less than 10 FDD terminals active at the same time. These values are calculated on the basis of outage, where the interference becomes too high so that a base station or a terminal loses its connections and a call or even all calls are dropped, being 5%.

If, for example, the first TDD base station 116 is located at a radius of $r_b = 500$m and assuming 5 active FDD terminals and an identical data rate to the FDD base station 106, capacity exists for an additional 15 TDD terminals within the first TDD cell 306. Alternatively, this additional capacity can be shared between existing TDD terminals $U_1, \ldots, U_n$, or used for a single existing user, for example, by increasing the data rate of the first TDD terminals U_1 by a factor of 15. Optimum results have been obtained in the

above simulations when the TDD base station 116 is located between approximately 200 and 500m from the FDD base station 106.

The above results of simulations are based upon a spatially uniform distribution of FDD terminals and imply an average over infinite user distributions. However, it should be appreciated that in any environment there is likely to be constellations of terminals which affect the available capacity within the band of FDD frequencies 108, 110. In particular, certain distributions of FDD terminals 318 will result in an increase in capacity, or a maintenance in capacity for an additional number of terminals, whereas other distributions will result in a decrease in capacity.

It should be appreciated that although the above embodiments have been described in relation to particular multiple access schemes used in conjunction with the duplexing techniques any multiple access scheme may be employed, for example, TDMA, CDMA, Space Division Multiple Access (SDMA), or Frequency Division Multiple Access (FDMA).

Although the above embodiments have been described in the context of the second duplexing technique using a portion of the frequency band of the first duplexing technique, it should be appreciated that the converse arrangement is also possible, i.e. the first duplexing technique using at least a portion of the band of frequencies of the second duplexing technique, such as at least one FDD terminal 318 using a portion of the unpaired TDD band of frequencies 118.

CLAIMS

1. A communications system comprising a first duplexing technique to enable communication between a first base station and a first plurality of terminals, a second duplexing technique to enable communication between a second base station and a second plurality of terminals, and frequency allocation means arranged to allocate at least a portion of a frequency band allocated to the first duplexing technique to a terminal so as to enable the terminal to operate in accordance with the second duplexing technique within the frequency band allocated to the first duplexing technique.

2. A system as claimed in Claim 1, wherein the first duplexing scheme is a Frequency Division Duplex (FDD) technique.

3. A system as claimed in Claim 1, wherein the second duplexing scheme is a Time Division Duplex (TDD) technique.

4. A system as claimed in Claim 1, wherein a first multiple access scheme is associated with the first duplexing technique.

5. A system as claimed in Claim 1,wherein a second multiple access scheme is associated with the second duplexing technique.

6. A system as claimed in Claim 4, wherein the first multiple access scheme is one of Code Division Multiple Access (CDMA), Time Division Multiple Access (TDMA), Space Division Multiple Access (SDMA) or Frequency Division Multiple Access (FDMA).

CLAIMS

1. A communications system comprising a first duplexing technique (100) to enable communication between a first base station (106) and a first plurality of terminals (104, 318), a second duplexing technique (102) to enable communication between a second base station (116) and a second plurality of terminals (114, U1, U2,.....Un); the first and second base stations (106, 116) serving terminals in respective but at least overlapping areas (302; 306, 308, 310) and the first and second duplexing techniques (100, 102) having respective frequency bands (108, 110; 118) associated therewith, characterised in that: the first duplexing technique (100) comprises a Frequency Division Duplex (FDD) technique; the second duplexing technique (102) comprises a Time Division Duplex (TDD) technique; and that, in order to increase the communications-handling capacity of the system, provision (404) is made for detecting spare capacity (400, 402) in a frequency band (108) associated with the FDD technique (100), and for allocating spare capacity so detected to support TDD communication between said second base station (116) and one or more of said second plurality of terminals (U1) without interrupting contemporaneous FDD communication between said first base station (106) and said first plurality of terminals (104, 318).

2. A system as claimed in Claim 1, wherein a first multiple access scheme is associated with the first duplexing technique.

3. A system as claimed in Claim 1, wherein a second multiple-access scheme is associated with the second duplexing technique.

4. A system as claimed in Claim 2, wherein the first multiple access scheme is one of: Code Division Multiple Access (CDMA), Time Division Multiple Access (TDMA), Space Division Multiple Access (SDMA) or Frequency Division Multiple Access (FDMA).

5. A system as claimed in Claim 3, wherein the second multiple access scheme is one of: Code Division Multiple Access (CDMA), Time Division Multiple Access (TDMA), Space Division Multiple Access (SDMA) or Frequency Division Multiple Access (FDMA).

6. A system as claimed in any preceding claim, wherein at least a portion (110) of the frequency allocation of the first duplexing technique (100) is used to transmit FDD downlink traffic during substantially all time slots associated with the second duplexing technique (102).

7. A system as claimed in any preceding claim, wherein a terminal (U1) operating in accordance with the second duplexing technique within the band (108) of frequencies allocated to the first duplexing technique is arranged to transmit delay-tolerant data.

8. A system as claimed in any preceding claim, wherein a terminal (U1) operating in accordance with the second duplexing technique within the band (108) of frequencies allocated to the first duplexing technique is arranged to receive delay-tolerant data.

9. A system as claimed in Claim 7 or Claim 8, wherein the delay-tolerant data is packet data.

10. A system as claimed in any preceding claim, wherein the means (404) provided for allocating spare capacity is arranged to determine a band (400, 402) of frequencies within a respective frequency band (108, 110) associated with the first duplexing system (100) on the basis of mutual interference criteria.

11. A system as claimed in Claim 10, wherein the means (404) provided for allocating spare capacity employs a dynamic channel allocation algorithm in order to evaluate said mutual interference criteria.

12. A system as claimed in Claim 3, wherein the second multiple access scheme has a guard time (tg), the terminal (U1) being arranged to use any capacity available in the band of frequencies associated with the first duplexing technique (100) during the guard time.

13. A system as claimed in any preceding claim, wherein the second base station (116) is located between about 200 and 500m from the first base station (106).

14. A system as claimed in any preceding claim, wherein the second plurality of terminals (114, U1, U2,.....Un) includes the terminal (U1).

15. A system as claimed in any of claims 1 – 13, wherein the terminal (Un+1) is a new terminal previously unaffiliated to the second base station (116).

16. A method of improving capacity in a communications system comprising a first duplexing technique (100) to enable communication between a first base station (106) and a first plurality of terminals (104, 318), a second duplexing technique (102) to enable communication between a second base station (116) and a second plurality of terminals (114, U1, U2,.....Un); the first and second base stations (106, 116) serving terminals in respective but at least overlapping areas (302; 306, 308, 310) and the first and second duplexing techniques (100, 102) having respective frequency bands (108, 110; 118) associated therewith, characterised by:

the first duplexing technique (100) utilising Frequency Division Duplex (FDD);

the second duplexing technique (102) utilising Time Division Duplex (TDD); and by the steps of:

detecting spare capacity (400, 402) in a frequency band (108) associated with the FDD technique (100); and

allocating spare capacity so detected to support TDD communication between said second base station (116) and one or more of said second plurality of terminals (U1) without interrupting contemporaneous FDD communication between said first base station (106) and said first plurality of terminals (104, 318).

17. A terminal for use in a system comprising a first duplexing technique (100) to enable communication between a first base station (106) and a first plurality of terminals (104, 318), a second duplexing technique (102) to enable communication between a second base station (116) and a second plurality of terminals (114, U1, U2,.....Un); the first and second base stations (106, 116) serving terminals in respective but at

least overlapping areas (302; 306, 308, 310) and the first and second duplexing techniques (100, 102) having respective frequency bands (108, 110; 118) associated therewith, characterised by the first duplexing technique (100) comprising a Frequency Division Duplex (FDD) technique; the second duplexing technique (102) comprising a Time Division Duplex (TDD) technique; and by the terminal (U1; Un+1) being arranged to receive an allocation of at least a portion (400, 402) of a frequency band (108) associated with the first duplexing technique (100) and to operate in accordance with the second duplexing technique (102) within said frequency band (108) associated with the first duplexing technique (100).

18. A base station (116) for use in a system comprising a first duplexing technique (100) to enable communication between another base station (106) and a first plurality of terminals (104, 318), the first-mentioned base station (116) supporting a second duplexing technique (102) for communication with a second plurality of terminals (114, U1, U2,.....Un); the first and second base stations (106, 116) serving terminals in respective but at least overlapping areas (302; 306, 308, 310) and the first and second duplexing techniques (100, 102) having respective frequency bands (108, 110; 118) associated therewith, characterised by the first duplexing technique (100) comprising a Frequency Division Duplex (FDD) technique; the second duplexing technique (102) comprising a Time Division Duplex (TDD) technique; and by the first-mentioned base station being arranged to allocate at least a portion (400, 402) of a frequency band (108) associated with the first duplexing technique (100) to a terminal (U1) so as to enable the terminal (U1) to operate in accordance with the second duplexing technique (102)

within said frequency band (108) associated with the first duplexing technique (100).

19. A base station as claimed in Claim 18, further comprising frequency allocation means (404) for allocating said at least a portion (400, 402) of the frequency band (108) associated with the first duplexing technique (100).

APPARATUS, METHOD OF AND SYSTEM FOR IMPROVING CAPACITY IN A COMMUNICATIONS NETWORK

ABSTRACT

In a telecommunications system (300), such as the Universal Mobile Telecommunications System (UMTS), a first duplexing technique (100) and a second duplexing technique (102) are employed. Bands of frequencies (108, 110, 118) are allocated to each duplexing technique (100, 102). However, due to asymmetry of telecommunications traffic, it is known that loading of the band of downlink frequencies (110) of the first duplexing technique (100) is likely to be high, whereas the loading of the band of uplink frequencies (108) of the first duplexing technique (100) in likely to be relatively low. Similarly, the loading associated with the second duplexing technique (102) is likely to be biased towards downlink telecommunications traffic. Consequently, the invention provides for frequency assignment means arranged to allocate at least a portion of a frequency band (400, 402) allocated to the first duplexing scheme (100) to a terminal so as to enable the terminal to operate in accordance with the second duplexing scheme (102) in the frequency band (400, 402) allocated to the first duplexing scheme (100).

(Fig. 4)

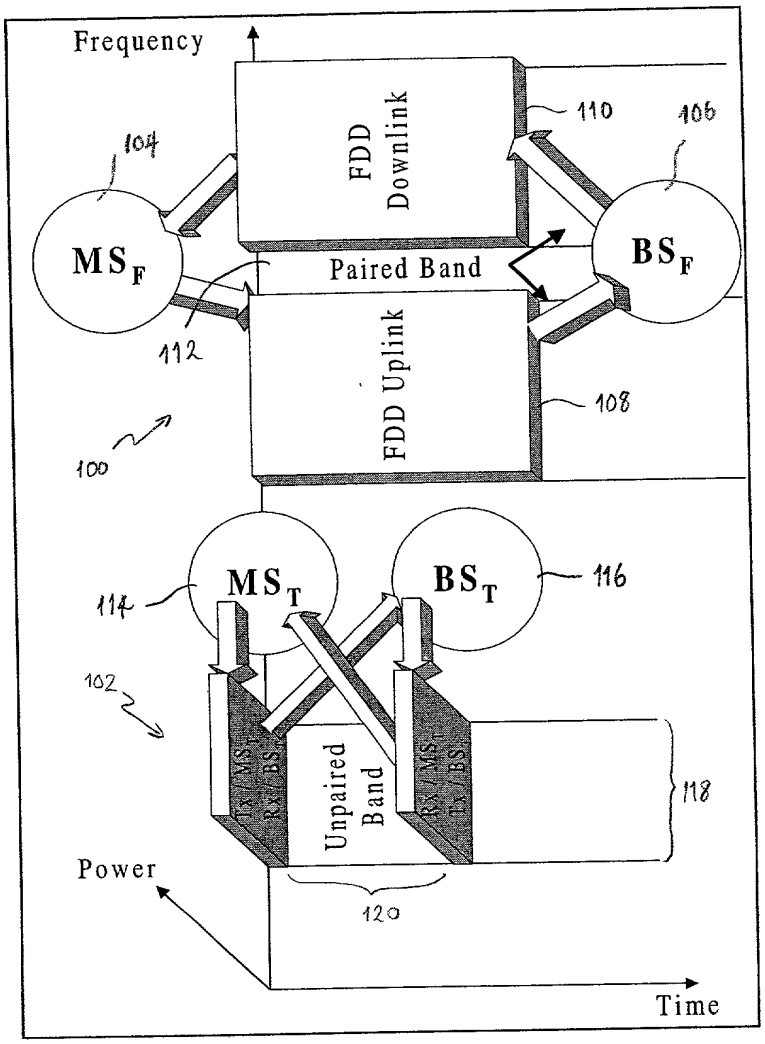
Frequency
FDD Downlink
110
106
104
MS F
BS F
Paired Band
112
FDD Uplink
108
100
MS T
BS T
114
116
102
Tx / MS
Rx / BS
Unpaired Band
Rx / MS
Tx / BS
118
Power
120
Time

FIGURE 1

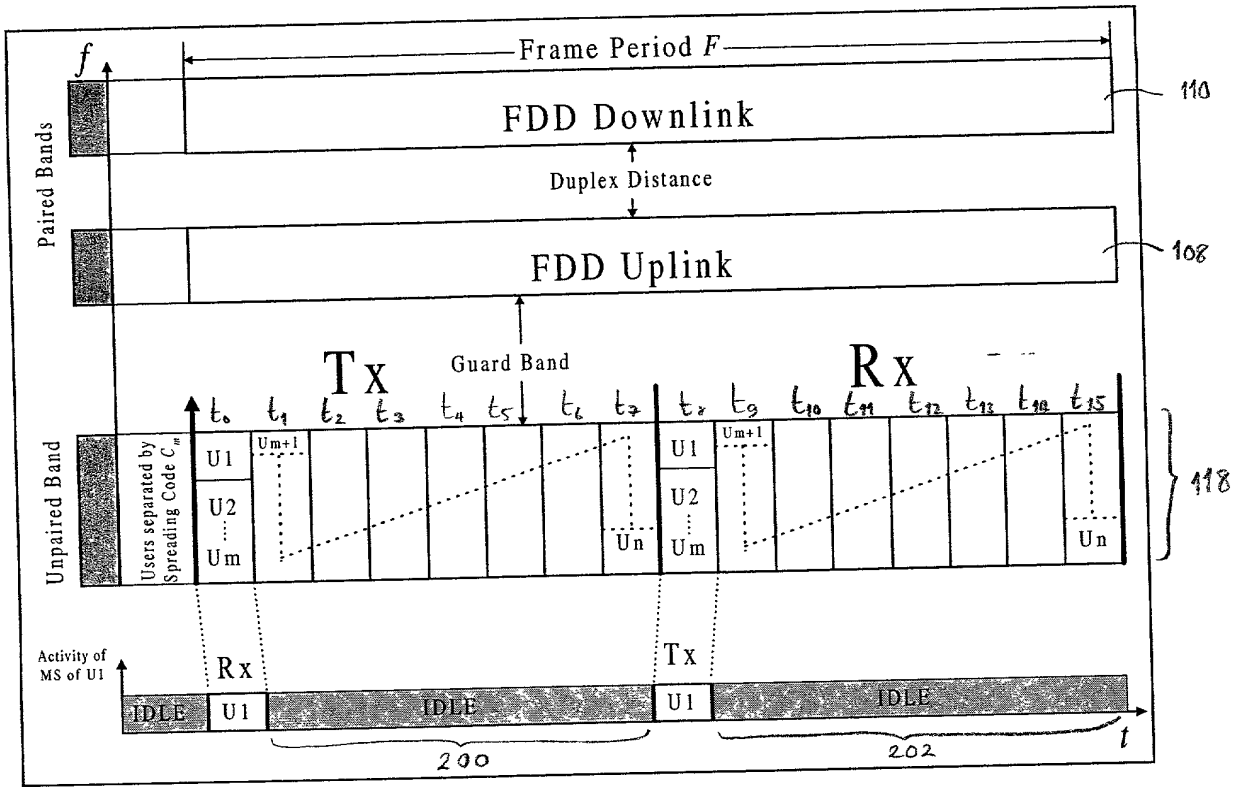
f
Frame Period F
Paired Bands
FDD Downlink
110
Duplex Distance
FDD Uplink
108
Guard Band
Tx
Rx
Unpaired Band
Users separated by Spreading Code C_m
U1
U2
Um
Um+1
Un
118
Activity of MS of U1
Rx
Tx
IDLE
200
202
t

FIGURE 2

▲ Users assigned to TDD Cell
× Users assigned to FDD Cell
◆ BS of TDD Cell
● BS of FDD Cell
——► Interference when using the FDD uplink for a TDD link
····· Desired Link

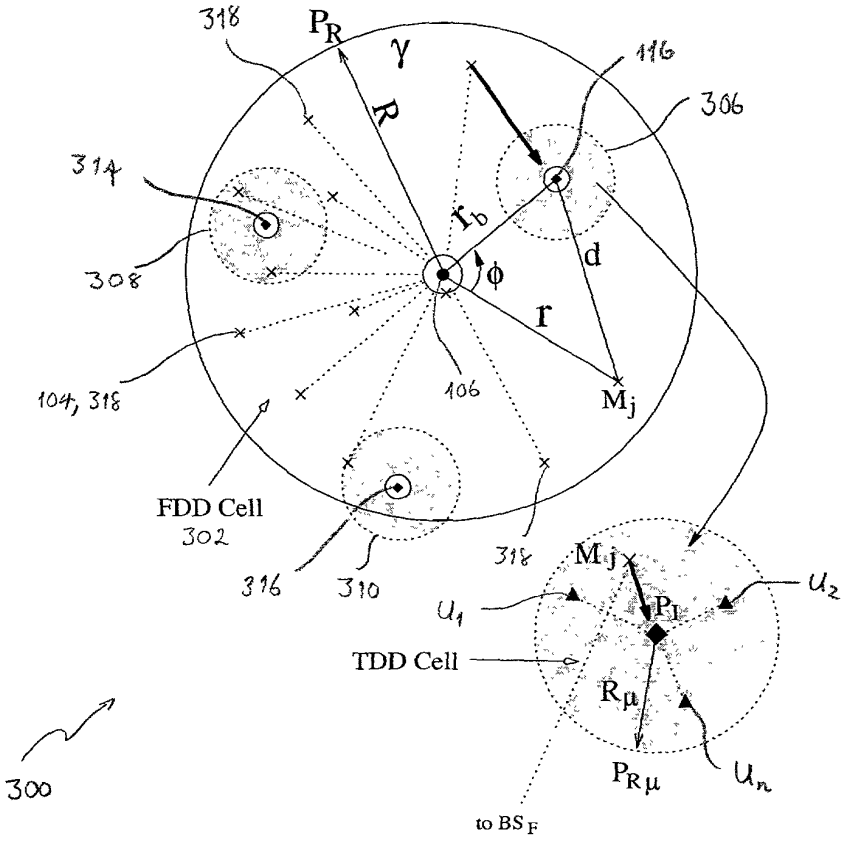

FIGURE 3

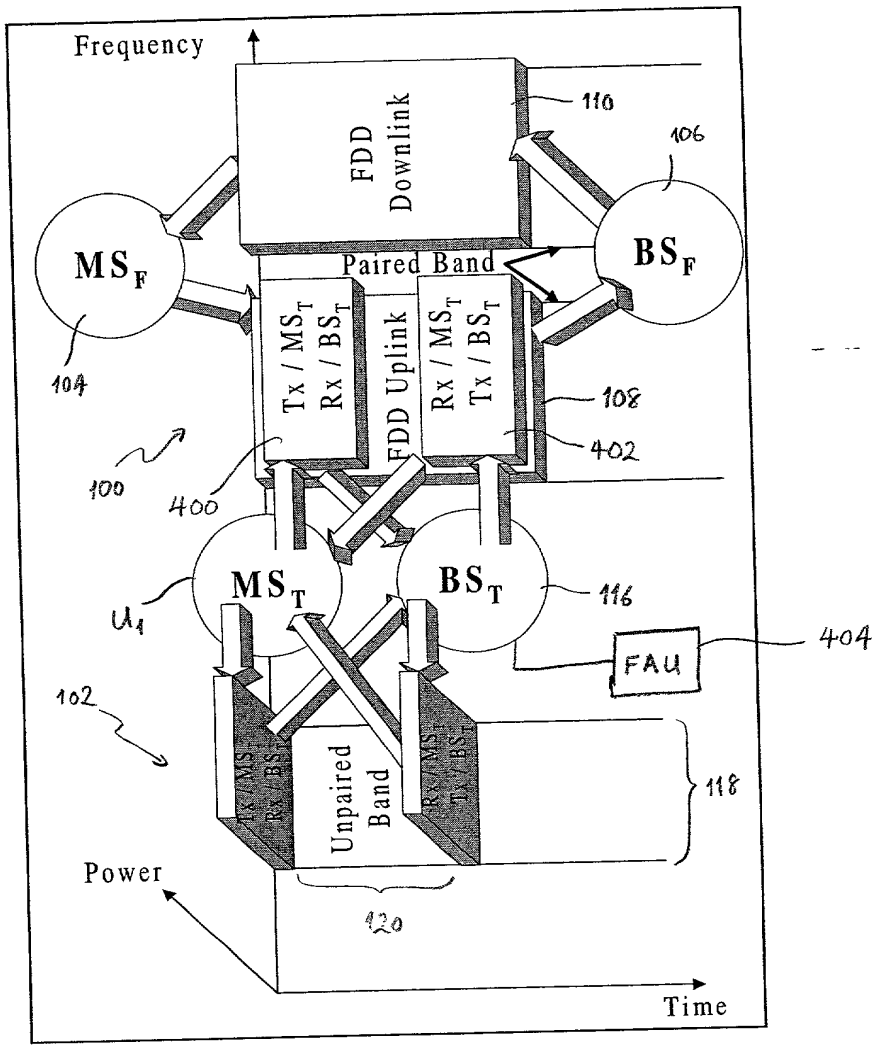
Frequency
FDD Downlink
110
106
MS_F
BS_F
Paired Band
Tx / MS_T Rx / BS_T
FDD Uplink
Rx / MS_T Tx / BS_T
104
108
402
100
400
MS_T
BS_T
116
U_1
FAU
404
102
Unpaired Band
118
Power
120
Time

FIGURE 4

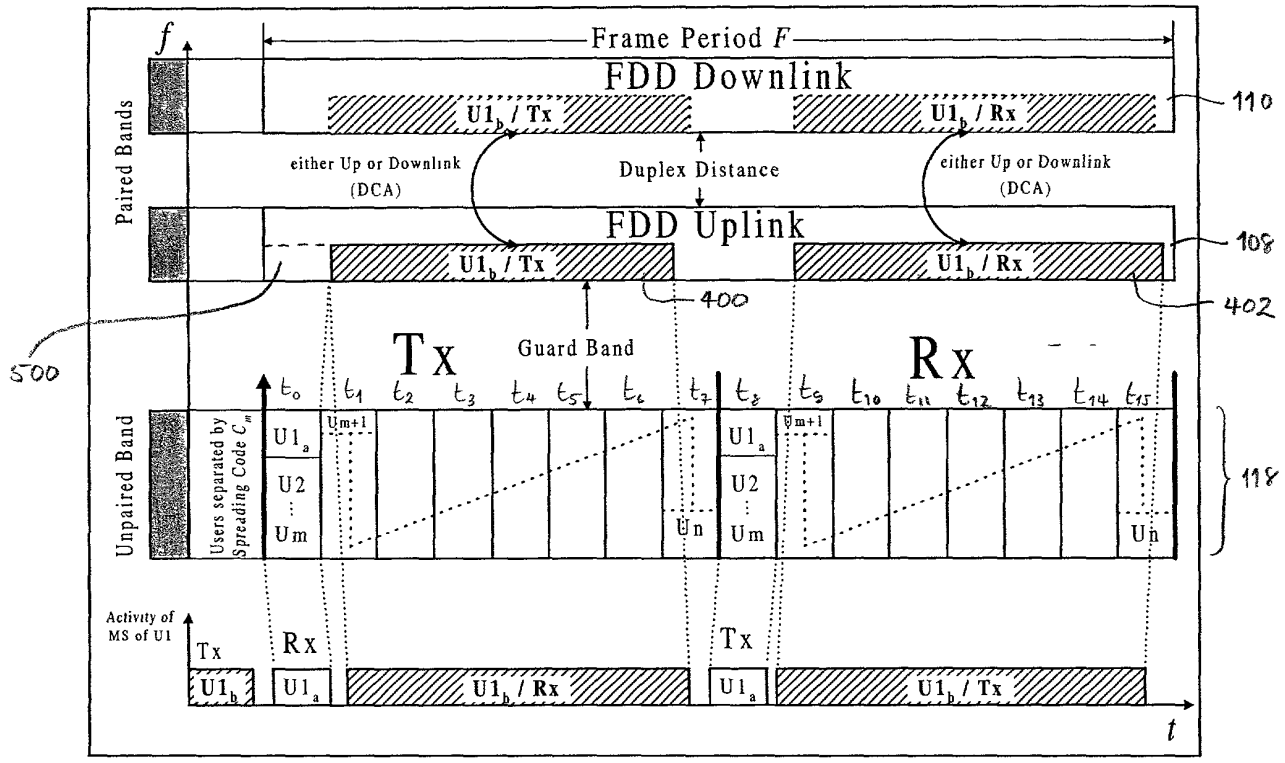
f
Frame Period F
FDD Downlink
U1b / Tx
U1b / Rx
110
Paired Bands
either Up or Downlink
(DCA)
Duplex Distance
either Up or Downlink
(DCA)
FDD Uplink
U1b / Tx
U1b / Rx
108
400
402
500
Guard Band
Tx
Rx
t0 t1 t2 t3 t4 t5 t6 t7 t8 t9 t10 t11 t12 t13 t14 t15
Unpaired Band
Users separated by Spreading Code Cm
U1a
U2
Um
Um+1
Un
118
Activity of MS of U1
Tx
Rx
t

FIGURE 5

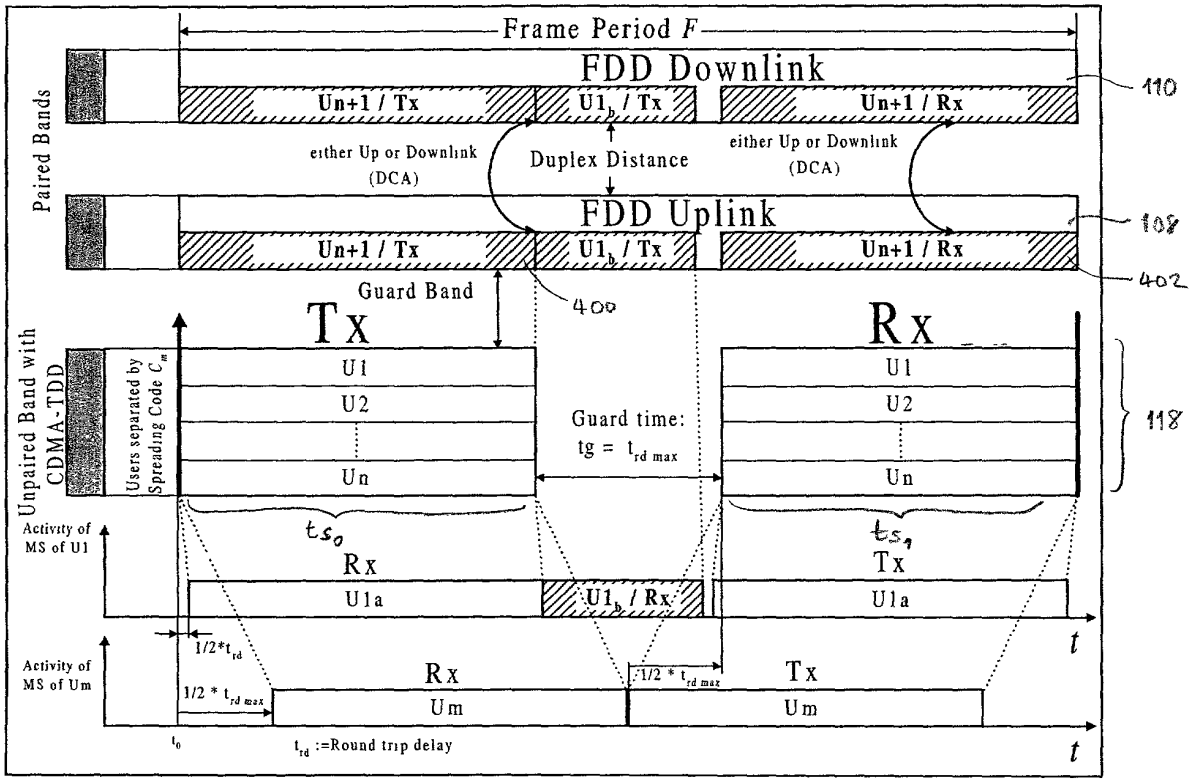
Frame Period F
FDD Downlink
Un+1 / Tx
U1b / Tx
Un+1 / Rx
110
either Up or Downlink
(DCA)
Duplex Distance
either Up or Downlink
(DCA)
FDD Uplink
Un+1 / Tx
U1b / Tx
Un+1 / Rx
108
402
Paired Bands
Guard Band
400
Tx
Rx
Unpaired Band with CDMA-TDD
Users separated by Spreading Code Cm
U1
U2
Un
Guard time:
tg = trd max
118
Activity of MS of U1
Rx
U1a
U1b / Rx
Tx
U1a
1/2*trd
Activity of MS of Um
1/2 * trd max
Rx
Um
1/2 * trd max
Tx
Um
t0
trd :=Round trip delay
t
t

FIGURE 6

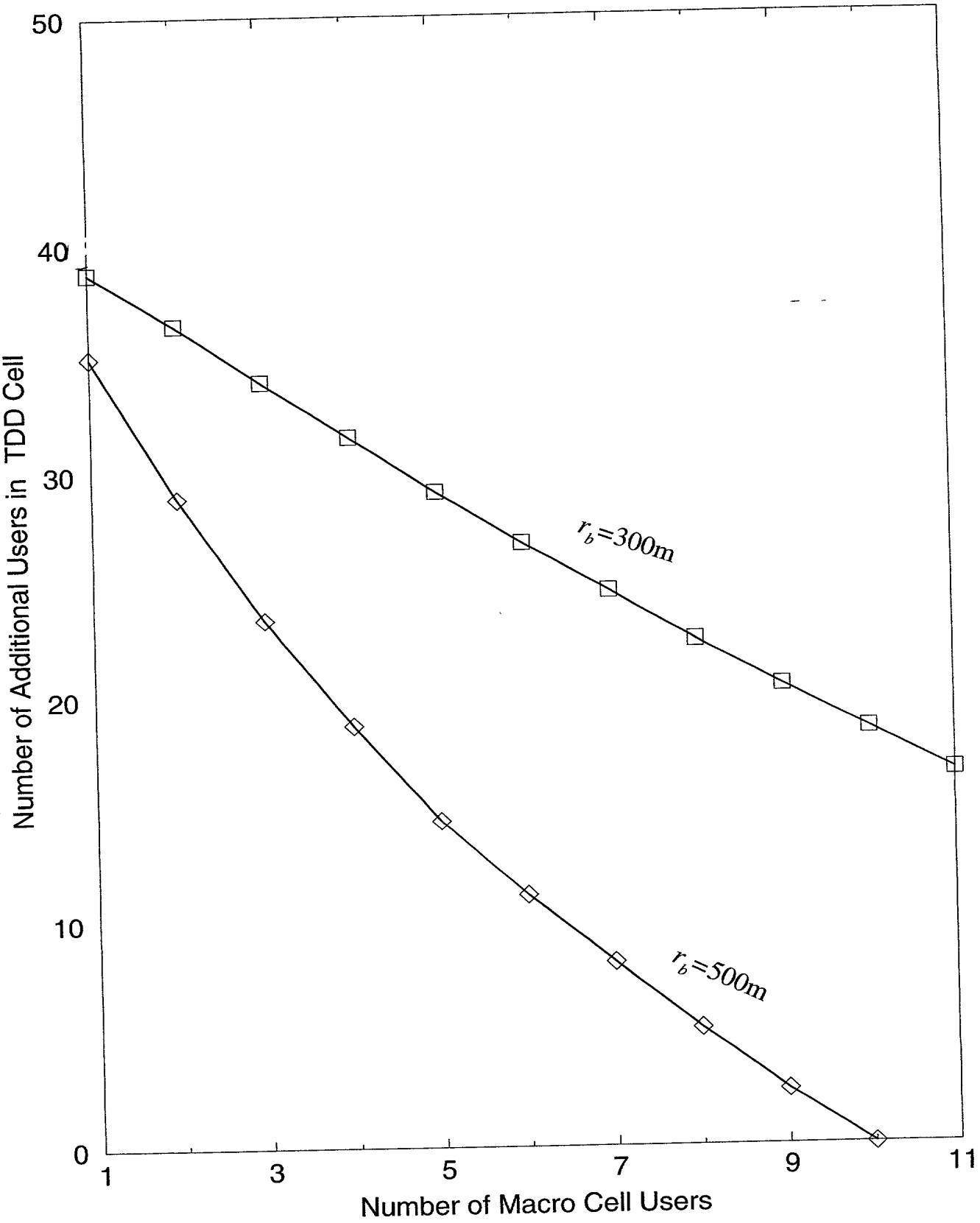
50
40
30
20
10
0
1
3
5
7
9
11
Number of Additional Users in TDD Cell
Number of Macro Cell Users
r_b=300m
r_b=500m

FIGURE 7

21 MAR 2001

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- 9 FEB 2001

1999 P04827 P68

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (includes Reference to PCT International Applications)	ATTORNEY'S DOCKET NUMBER 1934/49556

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

APPARATUS, METHOD OF AND SYSTEM FOR IMPROVING CAPACITY IN A COMMUNICATIONS NETWORK

the specification of which (check only one item below):

[ ] is attached hereto,

[ ] was filed as United States application
Serial No. _____
on _____
and was amended
on _____ (if applicable).

[X] was filed as PCT international application
Number PCT/GB99/02223
on 26 July 1999 (26.07.99)
and was amended under PCT Article 19
on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United State Code, §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. 119:

COUNTRY (if PCT indicate PCT)	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 USC 119
United Kingdom	98 16207.6	25.07.1998	[X] Yes [ ] No
			[ ] Yes [ ] No
			[ ] Yes [ ] No
			[ ] Yes [ ] No
			[ ] Yes [ ] No

Combined Declaration For Patent Application and Power of Attorney (Continued) (includes Reference to PCT International Applications)	ATTORNEY'S DOCKET NUMBER 1934/49556

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

PRIOR U.S. APPLICATIONS OR PCT INTERNATIONAL APPLICATIONS DESIGNATING THE U.S. FOR BENEFIT UNDER 35 U.S.C. 120

U.S. APPLICATIONS		STATUS (Check one)		
U.S. APPLICATION NUMBER	U.S. FILING DATE	PATENTED	PENDING	ABANDONED

PCT APPLICATIONS DESIGNATING THE U.S.					
PCT APPLICATION NO	PCT FILING DATE	U.S. SERIAL NUMBERS ASSIGNED (IF ANY)			

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (List name and registration number)

Herbert L. Cantor, Reg. No. 24,392; James F. McKeown, Reg. No. 25,406; Donald D. Evenson, Reg. No. 26,160; Joseph D. Evans, Reg. No. 26,269; Gary R. Edwards, Reg. No. 31,824; and Jeffrey D. Sanok, Reg. No. 32,169

Send Correspondence to:	Direct Telephone Calls to: (name and telephone number)
Evenson, McKeown, Edwards & Lenahan, P.L.L.C. 1200 G Street, N.W., Suite 700 Washington, D.C. 20005	(202) 628-8800

201	FULL NAME OF INVENTOR	FAMILY NAME HAAS	FIRST GIVEN NAME Harald	SECOND GIVEN NAME
	RESIDENCE & CITIZENSHIP	CITY Edinburgh	STATE OR FOREIGN COUNTRY United Kingdom	COUNTRY OF CITIZENSHIP United Kingdom
	POST OFFICE ADDRESS	POST OFFICE ADDRESS 42 Craigmillar Park	CITY Edinburgh	STATE & ZIP CODE/COUNTRY EH16 5PS United Kingdom
202	FULL NAME OF INVENTOR	FAMILY NAME POVEY	FIRST GIVEN NAME Gordon	SECOND GIVEN NAME Johnston Robertson
	RESIDENCE & CITIZENSHIP	CITY Kirkcaldy	STATE OR FOREIGN COUNTRY United Kingdom	COUNTRY OF CITIZENSHIP United Kingdom
	POST OFFICE ADDRESS	POST OFFICE ADDRESS 3 Forbes Terrace, Salisbury Street	CITY Kirkcaldy	STATE & ZIP CODE/COUNTRY KY2 5HW, United Kingdom
203	FULL NAME OF INVENTOR	FAMILY NAME	FIRST GIVEN NAME	SECOND GIVEN NAME
	RESIDENCE & CITIZENSHIP	CITY	STATE OR FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP
	POST OFFICE ADDRESS	POST OFFICE ADDRESS	CITY	STATE & ZIP CODE/COUNTRY

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

SIGNATURE OF INVENTOR 201	SIGNATURE OF INVENTOR 202	SIGNATURE OF INVENTOR 203
Harald Haas	Gordon Povey	
DATE 19/03/01	DATE 7/2/01	DATE